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EXECUTIVE SUMMARY CONCERNING THE IMPACT OF ADVANCED MAINTENANCE--ETC(U)

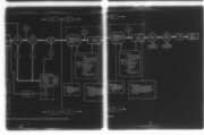
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**EXECUTIVE SUMMARY CONCERNING THE IMPACT
OF ADVANCED MAINTENANCE DATA AND
TASK ORIENTED TRAINING TECHNOLOGIES ON
MAINTENANCE, PERSONNEL, AND TRAINING SYSTEMS**

Prepared for
Department of Defense
By
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March 1978



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LABORATORY

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This executive summary was submitted by Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433, in partial response to 23 June 1977 Secretary of Defense Memorandum, under project 1710, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

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This technical report has been reviewed and is approved for publication.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

DAN D. FULGHAM, Colonel, USAF
Commander

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18. SUPPLEMENTARY NOTES This executive summary, together with its companion paper (AFHRL-TR-78-25; in press) have been prepared in partial response to the 23 June 1977 Office of the Secretary of Defense Memorandum, subject: "Management Review of Maintenance Training and Performance Aids." The memorandum was prepared as a result of a formal management review meeting held on 1 through 3 February 1977. Two major conclusions of that meeting are	19. KEY WORDS (Continue on reverse side if necessary and identify by block number) life cycle costs head/book trade off job performance aids (JPA) costs of ownership of hardware job and task analyses aptitude tests technical data presentation technical training objectives technical training personnel selection criterion referenced tests vocational education objectives maintenance training human subsystems maintenance effectiveness symbolic substitute job tests job oriented training human factors measures job task performance tests human factors in life cycle costs	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This paper is an executive summary of a more extensive white paper concerning the <i>impact</i> of improved maintenance guidance and information (IMG&I), as well as task oriented training (TOT) technologies on DOD maintenance, personnel and training systems. The IMG&I considered include fully proceduralized job performance aid (FPJPA) technology for both non-troubleshooting (non-TS) and troubleshooting (TS) tasks; the Army "New Look" for non-TS tasks; and for TS tasks only: traditional and enriched FORECAST aids, traditional and enriched logic tree troubleshooting aids (LTTA), and traditional and Air Force symbolic integrated maintenance system (SIMS), as well as a newer form of SIMS called functionally oriented maintenance manuals (FOMM). However, the technologies or concepts, whose effectiveness are supported by comparative hard data, include only: FPJPA, FORECAST aids, enriched LTAA, and AF SIMS. These hard data indicate that quality		

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addressed in the memo, namely, (1) the need to implement an existing technology base in job performance aid manuals, and (2) the need for more effort on integrated *technical data*, training, and personnel support systems that are based on analysis of the job task requirements. The first requirement was assigned to the Navy and fulfilled by DPRDC TR 77-33, "Symposium Proceedings: Invitational Conference on Status of Job Performance Aids Technology," May 1977.

This summary, and its companion white paper, addresses the second requirement which specifically addresses the requirement for the preparation of such a paper "on the applicability of job aids and the impact on the personnel and training systems." Included in this requirement is a discussion of "the applicability of job aids, training or both to enhance *military jobs proficiency*," as well as the identification of service and DOD policies that restrict payoffs in this area. (Industrial approaches to task analysis, job aids, training and personnel utilization are also discussed.)

The author was designated as chairman of a committee which included Dr. Robert Blanchard of the Navy Personnel Research and Development Center, San Diego, CA; Mr. John K. Klesch of the Army Training Development Institute, Ft Eustis VA; and Mr. Harry Maragides of Headquarters, Marine Corps, Washington, DC. After the first draft of the required paper was prepared a committee meeting was held at Headquarters, Air Force Human Resources Laboratory (AFHRL), Brooks AFB TX, on 13 December 1977. (Although Mr. Klesch was unable to attend, the other committee members, as well as LTC Roger Grossel of Department of Defense - OASD (MRA&L)WR and Mr. Robert Johnson of the Advanced Systems Division (AFHRL), Wright-Patterson AFB OH, were present.) The comments of this meeting resulted in some reorganization of the first draft, as well as the requirement for this summary.

This summary represents a portion of the exploratory development program of the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio. The preparation of this report was documented under task 171004, Job Performance Aids for Air Force Maintenance Technicians. The task is part of project 1710, Training for Advanced Air Force Systems. The effort represented by this paper was identified as work unit, 17100427. Mr. Robert Johnson was task scientist. Dr. Ross L. Morgan was project scientist.

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fully proceduralized maintenance technical data research and development proposals
fully proceduralized job performance aids (FPJPA)
training/job performance aid trade-off
measurement and evaluation maintenance training
measurement and evaluation vocational education
symbolic integrated maintenance system (SIMS)
FORECAST
job guide manuals (JGM)
job performance manuals (JPM)

behavioral analyses of tasks (BAT)
personnel systems for maintenance
fully proceduralized troubleshooting aids (FPTA)
curriculum development (technical training)
measurement and evaluation technical training
measurement and evaluation electronics training
improved maintenance guidance information (IMG&I)
symbolic integrated maintenance manuals (SIMMS)
Army "New Look"

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implementations of any of these technologies (or concepts) will result in more efficient performance of maintenance tasks than the use of traditional maintenance manuals (TMM). (In this regard, there are no hard data which indicate that FOMMs are more effective than AF SIMS.) But, by far the most dramatic reductions of life cycle costs (LCC) of hardware ownership can be realized by the quality integrated application of three of these types of IMG&I with TOT: i.e., FPJPA, FORECAST TS Aids and enriched LTAA. Of these, FPJPA have the most potential.

This executive summary also indicates a number of human, hardware and software problems, and policies which are impeding, or will, impede the implementation of these money saving technologies. Although dramatic LCC reductions can be effected by the quality implementation of IMG&I and TOT technologies, such implementations require greater dollar investments in maintenance guidance documents and in training than the implementing establishments are accustomed to spend. But additional money is not enough - quality implementations require "know how." A mechanism must be developed which makes efficient and effective use of the "know how" of the developers of the technologies, and makes them responsible and accountable for their early implementations. In this regard, most past implementations have "watered down" such technologies.

Of special interest to executives and managers are two tables which consolidate the important attributes of various IMG&I types and TMM; a figure which summarizes the results of many DOD TOT studies; and a flow diagram which portrays a model for maximizing benefits of FPJPA, SIMS, and TOT technologies.

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EXECUTIVE SUMMARY CONCERNING THE IMPACT OF ADVANCED MAINTENANCE DATA AND TASK ORIENTED TRAINING TECHNOLOGIES ON MAINTENANCE, PERSONNEL, AND TRAINING SYSTEMS

I. INTRODUCTION

A large part of the Army's and Marine's, and almost all of the Navy's and Air Force's, primary missions are concerned with the development, operation and maintenance of complex hardware systems. The life cycle costs (LCC) of such hardware systems are extremely high and continue to rise. Important factors contributing to LCC are high maintenance personnel costs, high cost of spare parts, as well as the unnecessary usage of such costly spare parts.

A large portion of high maintenance personnel costs is contributed by the cost associated with first enlistment personnel. But because of consistently low reenlistment rates of DOD maintenance personnel, a large portion of DOD maintenance tasks must be performed by relatively inexperienced first enlistment personnel. The costs for supporting all first enlistment personnel are currently estimated at \$15,000 per person per year or \$60,000 for a four-year enlistment. But, generally the effective period of on-the-job performance of maintenance tasks for such personnel is relatively short (as low as one year in some cases), making the actual man/year labor costs of useful work from first enlistment personnel extremely high (as high as \$60,000 for one year of useful work).

At least two important factors contribute to this generally short, on-the-job performance time of first enlistment maintenance personnel. The entry training programs, both formal and on the job, for many maintenance personnel codes are or have been long. (But in spite of such lengthy training programs, there is substantial evidence that maintenance tasks generally are not performed with high efficiency, either by first enlistment personnel or by personnel with longer on the job experience.) A second factor is the current "early out" policies of the services. If the escalation of DOD maintenance costs is to be controlled, ways must be found to increase the on-the-job utilization of first enlistment personnel, as well as to increase the efficiency with which all maintenance tasks are performed.

This paper is concerned with attaining these objectives by the proper selection and imple-

mentation of several available concepts and/or technologies. One purpose is to briefly describe these concepts and technologies which include job task performance tests (JTPT), task oriented training (TOT), and several types of maintenance directions and/or information (such as fully proceduralized job performance aids (FPJPA), logic tree troubleshooting aids (LTTA), symbolic integrated maintenance system (SIMS), and functionally oriented maintenance manuals (FOMM).). A second purpose is to outline the potential of each concept, or technology, for reducing each cost factor. A third purpose is to present a general implementation model or plan, which integrates compatible technologies for maximum cost savings. A final purpose is to identify current practices, policies, and problems which impede or prevent the implementation of such concepts and technologies.

II. IMPROVING THE PERSONNEL/ HARDWARE INTERFACE

The proper application and use of several technologies and/or concepts of improved maintenance guidance and information (IMG&I) could improve the performance of maintenance tasks. In addition, the concurrent and integrated application of a few of these maintenance guidance and information technologies (together with the task oriented training technology) would greatly reduce the entry training time for first enlistment maintenance personnel.

Improved Maintenance Guidance and Information Technologies and/or Concepts

Table 1 identifies the name and source of each of these technologies and/or concepts together with a brief description of each. Most of these technologies are aimed at improving the performance of troubleshooting tasks. Only two are aimed at improving the performance of non-troubleshooting (non-TS) tasks such as checkout tasks; align, adjust, and calibrate tasks; and install, remove, and replace tasks. Table 2 indicates these and other attributes for the technologies and/or concept listed in Table 1.

Table 1. Name and Brief Descriptive Information Concerning Improved Maintenance Guidance and Information (IMCA), as well as Traditional Maintenance Manuals

Short Title or Acronym	Title or Description Statement	Source(s)	Other Name(s)	Remarks
FPIPA	Fully Proceduralized Job Performance Aid (FPIPA) Technology	AFHRL TR-73-4 (Joyce et al., 1973a, 1973b, 1973c)	1. AFHRL Exploratory Development 2. Air Force Project PIMO ^a 3. AFHRL Advanced Development 4. Vietnamization 5. NAUC Advanced Development ^b	1. Air Force "Job Guide" Manuals 2. OGMI ("Non-TS Tasks") 3. Army "Job Performance" Manuals (JPIM) 4. Non-TS Tasks 5. Air Force - "Fully Proceduralized Troubleshooting Aids (FPTSA)"
Amy "New Look"	Code Name for an Army TOT research project	Mil-M-63037(TM)	Army Material Development and Readiness Command (DARCOM) For Army by Human Resources Research Organization (Human RRO)	DARCOM has replaced JPIM with "New Look"
Traditional FORECAST		Human RRO TR-66-23 (Shriver & Trexler, 1966)	Cue Response Sets	
Enriched FORECAST		Draft Mil-M-362XX(TM) Parts I & II	U.S. Army Human Engineering Laboratory	Similar to traditional with some pictorial locators added
Traditional LTIA	Logic Tree Troubleshooting Aids (LTIA)	Mil-M-63037(TM) and Mil-M-63038	A traditional category— used in some TMM during WW II Army DARCOM C-141 Organizational level	Troubleshooting Trees LTIA with varying amounts of enrichment
Amy LTIA		Air Force Logistics Command (AFLC) Also—Johnson, et al., 1977	N/A	For AFHRL Study (Potter and Thomas, 1976) 1. Organizational level developed by Westinghouse 2. Intermediate level by Lockheed 3. LTIA with controlled enrichment
Enriched LTIA				
Traditional SIMS	Symbolic Integrated Maintenance System (SIMS)	Mil-M-24100A (Ships)	Symbolic Integrated Maintenance Manuals (SIMMS or SMM)	1. Heart of system Maintenance Dependency Chart (MDC) 2. Also blocky schematics and blocky information
AF SIMS		Mil-M-38799	1. Air Force Project PIMO 2. Vietnamization 3. AFLC	1. MDC with step-by-step procedures in standard language and pictorial locators 2. Less complex symbols than traditional MDC 3. Keyed schematics and key information
FOMM	Functionally Oriented Maintenance Manuals (FOMM)	Mil-M-24100B	N/A	1. More sophisticated and complex symbols than traditional MDC 2. Alternate columns on MDC in color 3. Keyed schematics and key information
TMM	Traditional Maintenance Manuals	N/A	Air Force Technical Orders (TO)	See AFHRL TR-75-82 (Foley, 1975) for description of categories

^aPresentation of Information for Maintenance and Operations (PIMO).

^bNaval Air Development Command and NAUC.

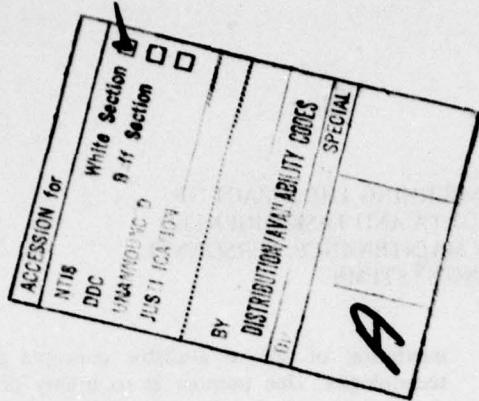


Table 2 also indicates that some of these concepts are effective with highly trained and/or experienced personnel, while others will support the performance of personnel with limited experience and/or training. The effectiveness of a few are supported by hard data, while others are not. Where comparative hard data have been gathered for a concept, they have indicated that the use of the concept (or technology) by highly trained and experienced personnel would result in more efficient performance of the categories of maintenance covered (non-TS or troubleshooting (TS) tasks or both) than the use of traditional maintenance manuals (TMM). The key word in this statement is "use." An improved IMG&I concept or technology *must* be used during the performance of tasks to be effective.

Comparative Effectiveness of Various IMG&I for Highly Trained and/or Experienced Personnel

The comparative hard data produced by the various studies, referenced in Table 2, indicate the following effectiveness relationships for IMG&I when used by highly trained and/or experienced personnel.

For non-TS tasks:

- (1) FPJPA \gg TMM

For TS tasks:

- (1) FPJPA $>$ Enriched LTTA \gg TM
- (2) Traditional FORECAST \gg TMM
- (3) AF SIMS \gg TMM

Note: $>$ More effective than.

\gg Much more effective than.

The *use* of any of the indicated improved technologies in lieu of TMM would improve the efficiency of maintenance personnel. This improved efficiency would be reflected in reduced spare parts usage, shortened cross training on unfamiliar hardware and, perhaps, increased numbers of maintenance tasks performed.

IMG&I and Potential for Reducing Maintenance Personnel Costs

However, if LCC are to be greatly reduced, those technologies that maximize the utilization time and efficiency of first enlistment personnel must be fully exploited. This objective requires the application of those technologies which are not only effective for improving maintenance efficiency, but also have potential for reducing entry training requirements. Table 2 indicates that only three technologies, for which hard data are avail-

able, meet both these criteria; i.e., FPJPA, traditional FORECAST and, by projection, enriched FORECAST. The hard data indicate the following effectiveness relationships.

For non-TS tasks:

- (1) FPJPA \gg TMM

For TS tasks:

- (1) FPJPA \gg TMM
- (2) Traditional FORECAST \gg TMM

(Although there are hard data concerning LTTA, the subjects used had no experience, but had received long initial formal training.)

Currently, there are no hard data which indicate the relative effectiveness between FPJPA and FORECAST aids for reducing entry training requirements. However, an analyses of each technology or concept based on consideration of the developmental requirements including task identification and analyses products (TI&A), content and format indicates that the FPJPA technology requires the user to store and recall *less* guidance and information for task performance than the other technologies or concepts—thus reducing the task training requirements for entry, as well as experienced personnel. *Expressed in other terms, the FPJPA technology relegates more maintenance guidance and information to the "book" and less to the "head" than do other technologies or concepts.* Compared on the basis of like analyses, the comparative potential of the applicable technologies for reducing entry training time and for increasing the maintenance efficiency of first enlistment personnel is indicated as follows:

For non-TS tasks:

- FPJPA \gg New Look

For TS tasks:

- FPJPA \gg Enriched FORECAST \approx Enriched LTTA

Note: \approx of equivalent effectiveness.

(Enriched rather than traditional FORECAST aids are included in these statements. Enriched FORECAST aids relegate more to the "book" than the traditional variety.)

Based on the results of these analyses, Table 3 indicates combinations of technologies which would be effective for reduction of initial training time for first enlistment personnel. These are listed in the order of their potential for reducing initial training time as well as for increasing maintenance efficiency.

The indicated relative effectiveness for these combinations can be expressed as a formula; i.e.:

$$1 \gg 2 \approx 3$$

Table 2. Important Attributes of Various IM&L and TMM

Technology and/or Concept	Non-TS Tasks	TS Tasks	Development Requirements	Step-by-step Directions in Standard Language	Keyed pictorial locators of Functional Units	Effectiveness with Varying Degrees of Training and Experience						Key Documents Presenting Hard Data	Specification and/or Guidance Documents	Remarks	
						Use	Requirement	High Level of Team Proficiency	Minimally Trained and Experienced	Highly Trained and/or Experienced	Aptitude Requirements				
FPIPA	X	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High and/or Medium	Yes	Serendipity Inc, 1969 Potter & Thomas, 1976 (I,II,III), Elliott, 1967 Mullen & Joyce, 1974 Shriver & Foley, 1975 Shriver, 1975	AFHRL-TR-73-42 (I,II,III), (Joyce et al., 1973a, 1973b, 1973c)	Data indicates minimum training requirements for entry personnel
Army "New Look"	X	Optional	Optional	No	Some	Yes	Possibly	Presumed	Highly and possibly medium	No	High and/or Medium	Yes	Shriver et al., 1964	Mil-M-63037(TM)	Specification does not require standard content for directions or pictorial locators.
Traditional FORECAST	X	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	High and/or medium	Yes	Draft Mil-M-632XX(TM) Part I*	Mil-M-632XX(TM)	Data indicates greatly reduced training requirements for entry personnel.
Enriched FORECAST	*	X	Yes	Some	Yes	Yes	Yes	Yes	Yes	Yes	High and/or medium	Yes	None	None	Enriched by adding pictorial locators.
Traditional LTIA	X	No	No	No	Yes	No	No	Presumed	High only	No	High only	No	Mil-M-63037(TM)	Mil-M-63038	Mil-M-63037(TM) and Mil-M-63038
Army LTIA	X	Optional	No	Optional	Yes	Possibly	Presumed	Highly and possibly medium	High and possibly medium	Yes	High only	No	None	None	Inexperienced subjects had completed long entry training.
Enriched LTIA	X	Yes	Some	Yes	Yes	Possibly	Yes	High and possibly medium	High only	Yes	High only	No	Mil-M-24100A (Ships)	Mil-M-24100A (Ships)	MDC symbols for traditional SIMS more complex than for AF SIMS
Traditional SIMS	**	X	No	No	Yes	No	Presumed	High Only	High Only	Yes	High Only	Yes	Serendipity Inc 1969 (Hard data concerns PIMO SIMS)	Mil-M-38799	Mil-M-38799
AF SIMS	X	No	Yes in MDC	Yes in MDC	Yes	No	Yes	High Only	High Only	No	High Only	No	None	Mil-M-24100B	AF SIMS enriched by pictorial locators
FOMM	**	X	No	No	No	Yes	No	Presumed	High Only	No	Least Effective	High Only	All of the above referenced documents	Format only	MDC symbols for FOMM more complex than for either traditional or AF SIMS
TMM	Some	X	No	No	Yes	No	Least Effective	High Only	Yes	All of the above referenced documents	Format only	All hard data has indicated least effective for supporting maintenance	All hard data has indicated least effective for supporting maintenance	TMM, therefore, not part of concept.	

*Draft Mil-M-632XX (TM), Part I, provides FPIPA for non-TS tasks.

**Directions for some non-TS tasks are provided. These directions are similar to those provided by

Table 3. Indicating Three Combinations of IMG&I Technologies as to Their Effectiveness for Reducing Initial Training Time

Combination	Non-TS Tasks	TS Tasks	Order of Effectiveness
1	FPJPA	FPJPA	1
2	FPJPA	Enriched FORECAST	2.5
3	FPJPA	Enriched LTTA	2.5

Enriched LTTA are defined as TS aids of the same degree of enrichment as were produced for the C-141 aircraft, which were used for organizational level TS in the Air Force Human Resources Laboratory (AFHRL) study reported by Potter and Thomas (1976), and Potter, Hubbert, Landolfi, Rice, and Kearns (1976a, 1976b). At the request of Air Force Logistics Command (AFLC), AFHRL is now developing a draft specification which should insure the development of LTTA of consistently high quality from hardware to hardware. Such consistency will make the indicated training trade off for a cluster of hardware possible. The current specifications for developing Army LTTA do not ensure such consistency.

As to why "New Look" aids for non-TS tasks are not included in Table 3, the current specifications for developing these aids have a similar weakness. In addition, there are no hard data available that attest to their effectiveness for supporting the performance of such maintenance tasks.

Integrated Implementation of FPJPA and TOT Technologies

Figure 1 provides a summary of results of key research efforts concerning effectiveness of TOT technology. Six of the 11 TOT efforts indicated were support by the Army; *three*, by the Air Force, and two by the Navy. Most of these 11 efforts concern training for maintenance jobs supported by TMM. Since TMM provide much less guidance and in most cases less information than any of the combinations shown in Table 3, the maintainer must compensate for the TMM deficiencies. This, of course, requires a relatively longer and, therefore, more costly TOT program than when more effective maintenance guidance and information carry most of the guidance load.

This "head"/book trade off problem has been addressed by a few researchers. The Navy report by Theisen, Elliott, and Fishburne (1978) and the Air Force report by Mullen and Joyce (1974) concern integrated applications of FPJPA and

TOT technologies, and the report by Shriner, Fink, and Trexler (1964) concerns the integrated application of FORECAST and TOT technologies. Both integrations have proven effective; however, the FPJPA/TOT integration will usually result in shorter training. Since the thrust of this paper is for maximization of on-the-job time for first enlistment maintenance personnel, the discussions that follow will consider the potential impact of FPJPA/TOT integrations (Combination 1 shown in Table 3) on DOD personnel and training systems. But most of what is said would, also, apply to an integration of FPJPA-FORECAST Combination 2 (Table 3) and TOT. However, the TOT would be appreciatively longer because *less* of the guidance and information in FORECAST had been relegated to the book.

Considering the transitory nature of maintenance personnel, as well as their training, logic would dictate that maximum utilization be made of the "book" when determining the head/book trade off. What is put in the "book" remains in the book, the quality and quantity of its contents do not deteriorate with time, all copies of the book are identical, and the content of the book will never deteriorate from lack of use. On the other hand, what is relegated to the "head," or training, may never be fully and accurately assimilated by many individual maintainers and the amount of assimilation will vary from individual to individual. Once an individual has attained the desired task proficiency, such proficiency will deteriorate rather rapidly with lack of use. In addition, the individual's stay in DOD in most cases is relatively short, so whatever proficiency he has, is soon lost and the training cycle must be repeated for his replacement, ad infinitum.

The current state-of-the-art for IMG&I/TOT reflected by the previously referenced reports by Theisen et al. (1978); Mullen and Joyce (1974); and Shriner et al. (1964) attest to the feasibility of such trade offs. In addition, the AFHRL draft FPJPA specification and handbooks provide some guidance for FPJPA/TOT trade off. Substantial DOD maintenance gains can be realized by the

The purpose of this figure is to identify the types of controlled studies supporting IMG&I and/or TOT, to give the general flavor of their results and to direct the interested reader to available summaries and lists of references on job oriented training, technical data, and performance measurement.

The armed services have conducted at least 11 controlled studies concerning the effectiveness of job oriented training programs for maintenance. The experimental job oriented training programs developed for these studies have been aimed at several types of job situations. Some have been structured to train new military enlisted personnel to perform maintenance jobs involving a number of hardware systems. Other programs were aimed at existing single system jobs. For both these types or programs, the existing job situations were accepted without change. For at least two studies, the job situations were simplified for the experimental subjects by modified information or directions for performing job tasks and the TOT program for each was developed with the objective of training the subjects to perform the tasks of the simplified job.

The effectiveness of each of these 11 experimental job oriented training programs was compared under controlled conditions with the existing theory centered training programs used to train similar personnel. A summary of most of these studies together with a list of reports was made by Foley (1967). Further information concerning the more recent studies can be obtained from Elliott (1967), Elliott & Joyce (1968), Chalupsky & Kopf (1967), Pieper et al. (1970), Pickering & Anderson (1966), Steinemann & Hooprich (1967), Steinemann et al. (1967), Van Matre & Steinemann (1966), Mullen & Joyce (1974), Shriver et al (1964) and Theisen et al. (1978).

The last two documents report hard data which attest to the feasibility of and training gains from IMG&I/TOT trade offs. The report by Shriner et al., pertains to FORECAST TS aids/TOT trade offs applied to a small cluster of electronic hardware, whereas the report by Theisen et al., pertains to a FPJPA/TOT trade off for one hardware. The Mullen & Joyce report describes the demonstration of another FPJPA/TOT trade off, but contains no comparative hard data.

An indepth review of all these studies indicates that: (a) job oriented training subjects could perform the tasks of their jobs with much less on-the-job-training (OJT) than the control subjects, (b) medium and some low aptitude subjects were more successful in job oriented training programs than in traditional training programs, (c) job oriented training courses were shorter than conventional courses, and (d) when the jobs were modified with improved job instructions and information, the TOT was much shorter.

An indirect source of insight as to the questionable effectiveness of theory-based maintenance training programs is found in research on performance measurement. The student measurement programs in all theory-based training programs are heavily weighted with paper-and-pencil tests of theory and job knowledge. A student usually learns well those things on which he is tested. Foley's summary (1974) of the available performance measurement research literature indicates that the relationship between the test subjects' ability to actually perform the tasks of maintenance jobs and their scores obtained on theory or job knowledge tests is very low. Likewise, the correlation is low between school marks and measures of job performance. A strong inference can be drawn from these. The only way most personnel learn to perform job tasks is by practicing those job tasks properly. Learning job tasks by practice is what TOT is all about.

Figure 1. Research efforts supporting IMG&I/TOT trade off.

implementation of the current state-of-the-art. (However the ground rules for such trade offs could probably be greatly refined by further R&D. The accomplishment of this important area of R&D has been delayed for several years by the failure of appropriate DOD training establishments to support it. Hopefully, one outcome of the current R&D program of the Navy Personnel Research and Development Center (NPRDC) will be a refinement of IMG&I/TOT trade off ground rules.)

Use of Test Equipment. An often neglected key factor, concerning head/book trade off and the performance of maintenance tasks, is the requirement for high proficiency in use of test equipment. To date, most IMG&I developments have assigned the use of all test equipment functions to the "head" rather than the book. Under such conditions, the TOT must contain sufficient practice of test equipment functions to ensure "over learning." But, this is not enough, there must be periodic performance tests in the field to ensure that maintenance personnel sustain this necessary high proficiency. The model JTPT battery reported by Shriver and Foley (1974a) provides a sub-battery of JTPT for test equipment. Model task oriented programmed instruction packages (i.e., task oriented training) are available which provide "hands on" practice in the use of general electronic test equipment (see Scott & Joyce, 1975a through 1975l). Since such general test equipment are used across many hardware clusters, a most cost effective action for improving the quality of maintenance even with TMM would be a DOD-wide program for improving test equipment proficiency. Such a program would require only modifications and expansions of the available model TOT packages and JTPT battery.

Maximum Job Utilization of First Enlistment Personnel

Attention is directed to the portion of Table 4 concerning entry into the first enlistment. This portion of the table summarizes both the training gains and maintenance gains which can be expected from a quality implementation of the FPJPA and TOT technologies. The gains would, without a doubt, result in tremendous reductions in LCC of hardware ownership.

Requirement for High Quality Backup Support

It is estimated, based on hard data, that entry first enlistment personnel having received high quality TOT can accurately isolate 90 to 95 percent of hardware troubles using FPJPA (see Table

4, column 5, item 3, for first enlistment personnel). It should be emphasized that, based on available information, this level of accuracy greatly exceeds the present performance of most DOD maintainers. This superior TS performance alone would reduce spare parts usage and secondary damage of hardware by reducing the current great reliance on excess removal and replacement actions for fault correction.

But even though a quality integrated implementation of FPJPA and TOT technologies would greatly improve the current efficiency of maintenance, appropriate steps should be taken to insure the efficient solution of the 5 to 10 percent of faults that might elude isolation by FPJPA. The lower portion of Table 4 concerns the development of a cadre of backup personnel with the ability to efficiently isolate such elusive faults, as well as to perform other functions which will be discussed later.

III. VERSATILE MODEL FOR MAXIMIZING BENEFITS OF FPJPA AND TOT TECHNOLOGIES

Figure 2 appears as the foldout at the end of this paper. The flow chart displayed in this illustration represents a modification of a chart developed by Dr. Robert Blanchard as part of his planning for the current research program of the NPRDC, San Diego, California (Blanchard, 1978). The illustration also contains information displayed in Table 4. Most of the information found in that table is inserted at the appropriate places in the flow chart. Much of the chart has been designed to be self-explanatory, but some of its key blocks require discussion. To facilitate the use of the chart in the discussions that follow, each functional block on the chart has been numbered.

The chart (Figure 2) is divided into two parts by a heavy dashed line between Blocks 11 and 12. The portion of the chart to the left of this dashed line is designated as "First Term" functions. As used in this chart, "First Term" is applied to personnel who are in their first enlistment, and who have not extended their enlistments to take advantage of the broadbased training represented by Block 12. The portion of the chart to the right of this dashed line contains "Second Term" functions. "Second Term" is applied to first enlistment personnel who have extended their enlistment to take the broadbased training.

In many respects this is an extremely versatile model. For example, it can be applied to one hardware system or a cluster of hardware. However, to obtain the maintenance and training gains indi-

Table 4. Chart Displaying Proposed Maintenance TO Categories, Types of Training, and Expected Gains from Full Implementation

(1) Enlistment	(2) Categories of Job Aids	(3) Type of Training	(4) Training Gains Expected	(5) Maintenance Gains Expected
First (Entry)	1 FPJPA (Non-TS Tasks)	Short job-oriented training with supervised practice on	1 Length of initial training reduced by as much as percent.	1 Such personnel job ready at end of formal training.
	2 FPJPA (TS Tasks)	1 Use of FPJPA	2 Resulting in fewer people requiring training.	2 More effective performance at non-TS tasks.
		2 Use of Hand Tools.	Average, as well as, high aptitudes could be trained.	3 More effective performance of TS Tasks – estimate such personnel can isolate 90 to 95 percent of possible troubles.
		3 Use of Test Equipment	4 Shorter personnel build up time required for	4 More months on job due to shorter training time, thus fewer personnel in the Air Force.
		4 Safety practices	5 Minimum of cross training to unfamiliar equipments (provided FPJPA available on unfamiliar equipments).	5 Minimum of cross training to unfamiliar equipments (provided FPJPA available on unfamiliar equipments).
Extended first as well as second and beyond	1 FPJPA (Non-TS Tasks)	1 Reduction in initial OJT and job cross training.	6 More effective utilization of maintenance personnel during peck and/or emergency.	6 More effective utilization of maintenance personnel during peck and/or emergency.
	2 FPJPA (TS Tasks)	2 Reduction or elimination of formal special and supplemental training.	7 Fewer unsolved maintenance problems referred to depot :: reduction in depot maintenance.	7 Fewer unsolved maintenance problems referred to depot :: reduction in depot maintenance.
		3 For Unusual TS Tasks:	8 Fewer space parts consumed.	8 Fewer space parts consumed.
		4 MDC with pictorial locators	9 Less paper work generated.	9 Less paper work generated.
		5 Blocked schematics	10 Less secondary damage from unnecessary maintenance actions.	10 Less secondary damage from unnecessary maintenance actions.
SIMS or FOMM	3 MDC with pictorial locators	1 More effective training for backup personnel.	1 A larger number of highly effective backup maintenance personnel for performing unusual and difficult maintenance tasks.	1 A larger number of highly effective backup maintenance personnel for performing unusual and difficult maintenance tasks.
	4 Keyed information	2 Fewer people requiring long, broadbased training.	2 Fewer unsolved maintenance problems referred to depot :: reduction in depot maintenance.	2 Fewer unsolved maintenance problems referred to depot :: reduction in depot maintenance.
	5 Pictorials with	6 Pictorials with	7 Aircraft wiring diagrams.	7 Aircraft wiring diagrams.
		7 Aircraft wiring diagrams.	8 IPB	8 IPB
		9 Preservation, Shipping and Storage Info.	9 Preservation, Shipping and Storage Info.	9 Preservation, Shipping and Storage Info.

cated, there are five extremely firm requirements:

1. *Quality FPJPA must be developed for all the hardware in the cluster under consideration. Such aids must reflect the key characteristics and requirements of the FPJPA technology as discussed in Foley (1978). These include TI&A; standard language and keyed pictorials for maintenance instructions; appropriate format for the maintenance environment; as well as "hands on" validation of the effectiveness of the product by the contractor; "hands on" verification of the effectiveness of the product by the purchasing DOD agency; and warranty of the product by the contractor.*

2. *To be effective, these quality FPJPA must be used by each maintainer while he is performing his job tasks.*

3. *Quality TOT programs must be developed which support and complement the FPJPA for the cluster of hardware under consideration. The fit between the FPJPA and the TOT is extremely critical for efficient job performance of first term personnel.*

4. *The advancement of all first term maintenance personnel both in skill and pay levels must be accomplished on the basis of demonstrated ability to perform job tasks. This requires the elimination of all paper-and-pencil theory and job knowledge tests from first term advancement requirements. (Scores from such paper-and-pencil tests have little relationship to ability to perform maintenance tasks (Foley, 1974).)*

5. *After initial training, each first term maintainer must perform both non-TS and TS maintenance tasks on a full time basis for at least one year using FPJPA (Block 6). This is an extremely important requirement for the cost effective utilization of first enlistment personnel. Here is where the maintainer "pays for his or her keep"; demonstrates his potential usefulness to DOD including the demonstration of good work habits and of ability to use his hands; and thus earns the privilege of obtaining advanced training (Block 12).*

Key Features of the Model

Current Aptitude Tests (Block 1). Current DOD aptitude tests have been designed to select people who will do well in current entry maintenance training programs. For example, many current Air Force entry maintenance training programs require people with aptitudes of 80 percentile and above to successfully complete current academically oriented entry training programs. A large number of such personnel do not aspire to make maintenance

a career, accounting in part for low reenlistment rates as well as "early outs." However, both TOT and FPJPA research have indicated that most middle or medium aptitude, as well as high aptitude personnel, as measured by current aptitude tests, can successfully complete TOT training and can perform maintenance tasks adequately. So for the present, the current aptitude tests can be used for selecting entry maintenance personnel. One simply has to adjust the aptitude cutoff score.

Short Entry TOT (Block 3). This block represents integrated applications of the FPJPA and TOT technologies. In a short summary presentation; such as this, it is not feasible to discuss all of ramifications and possibilities for such integrated applications, but a few of the key and unique characteristics are mentioned.

1. *The meshing of the content of the FPJPA for the cluster of hardware under consideration and the content of the TOT represented by this block is an absolutely necessary ingredient for such applications. This meshing requires precise task identification for all hardware selected for the cluster, followed by a very careful trade off as to which tasks or parts of tasks for each hardware will be relegated to TOT and/or FPJPA. To achieve this, the same trade off ground rules must be applied for each hardware in the cluster (see Joyce, Chenzoff, Mulligan, & Mallory, 1973a, 1973b, 1973c).*

2. *TOT packages (for initial training) must be developed which require the trainee to perform "hands on" practice of key tasks using FPJPA on whichever hardware of the cluster is available for training purposes. Since the trainee will receive his instructions for performing such "hands on" practice, much of the TOT package will be a training management document identifying the tasks to be practiced. Such a TOT package will also provide instructions for practice on those activities which have been assigned to training; such as use of test equipment. Once the trainee has learned to perform tasks using one hardware he will be able to perform tasks on each of the other hardware in the cluster with a minimum of cross-training. Such cross-training packages must be developed as required covering only those activities not included in the FPJPA, nor in the initial package.*

3. *The physical location of the entry TOT programs can either be centralized in one location or decentralized; i.e., at or near the initial job assignment of each trainee. If quality FPJPA and quality TOT packages to match become available, on site job entry training similar to that utilized by the Office Products Division of IBM may become the most cost effective route for many DOD*

maintenance situations. (*In fact, the Army is now planning to conduct on-site initial training, but without quality FPJPA.*)

4. *The proposed TOT would practically force first term maintainers to use FPJPA to perform their tasks because that will be the only way these people will have been trained to do their job tasks.* This would reduce one of the current DOD maintenance problems, that of getting maintainers to use their maintenance instructions.

Job Task Performance Test (JTPT) Battery (Block 4). A JTPT battery, similar to the model described by Shriner and Foley (1974a), should be developed for each cluster of hardware. The use of such tests is another absolutely necessary ingredient for maximizing the utilization of first term maintainers. The objective of the proposed TOT programs is to teach people to perform maintenance tasks of a specific number of hardware items using FPJPA—the objective is not to teach people to pass paper-and-pencil theory and job knowledge tests. The only appropriate tests for insuring the achievement of such a task performance objective are JTPT. There is nothing really new about the idea of using JTPT as training criteria. They were used extensively by the Navy and Air Force during and after World War II (Foley, 1977). What is new, is their refinement (Shriner & Foley, 1974a).

In addition to their worth for ensuring the task performance ability of entry personnel, the use of JTPT provides the basis for a great improvement of the DOD posture concerning several equal-employment-opportunity (EEO) rulings of the U.S. Supreme Court. (These rulings have indicated that the selection of employees, as well as their promotion should be based on ability to perform job tasks (Alluisi, 1977).) It is worth noting that the Office Products Division of IBM uses task performance tests as the sole criteria for successful completion of entry training and as prime criteria for all career advancement. (AFHRL has support work which has produced some graphic symbolic substitute tests of promising empirical validity (Shriner & Foley, 1974b). However, the technology for developing symbolics requires more refinement before such tests can be recommended for operational use.)

"Skill Level" Upgrade on First Job (Block 6). The award of a 4-skill level is provided after about six months on the first job. This skill level will indicate that the maintainer has demonstrated his ability to perform his job tasks and has demonstrated good work habits. The award of this 4 level could be made on the basis of a supervisor's evaluation. This is a proposed new skill level.

Career Evaluation and Selection for Broadbased Training (Blocks 7 through 12). The career evaluation envisioned for Block 7 would be based on three factors. The *first* (a go, no-go factor) would be a comprehensive JTPT battery which would ascertain that the maintainer could perform a wide range of maintenance tasks using FPJPA and that he had a high degree of expertise in the use of test equipments. The *second* factor would be a supervisor's rating. The *third* factor would be an aptitude test battery for the broadbased training. If the maintainer successfully completed this evaluation process, he would be awarded the 5 skill and he would become eligible for an offer to extend his enlistment for broadbased training (Block 12).

Since the number of training spaces for such broadbased training would be limited, a successful completion of the career evaluation might not result in an immediate offer. The maintainer might have to continue working in the Block 10 status until there was an available opening. But whenever such an offer was made, it would be accompanied by an offer of a bonus. The amount of the bonus could vary with the needs of the services. Any 5 level individual who declined to extend his enlistment (and any individual who failed the Block 7 evaluation) would continue to work in a Block 10 status as indicated on the flow chart.

Potential Dollar Gains from Improved Utilization of First Term Personnel (Blocks 6 and 10). Consider those personnel that remain in the FPJPA mode for their entire first enlistment. An addition of times in Blocks 6 and 10 indicates a total of from three to three and one half years of effective job time. Based on the estimated total of \$60,000 personnel cost for a 4-year first enlistment individual, mentioned earlier; three years of effective job time would cost DOD \$20,000 per year. When compared to some individuals in the current job situation, from whom only one year of effective job time is realized, (\$60,000 per man-year), this would be a saving of \$40,000 per man. Applied only to 100 individuals, this would result in a \$4,000,000 saving. Consider also the individual who, after 18 months, extends his enlistment for broadbased training (Block 12). Based again on the \$60,000 figure for four years, DOD will have received one full year of productive labor for \$22,500 before he extends. And, for his extended four years, DOD can expect three full years of effective job time at \$20,000 per year. These manpower savings could result in more qualified maintenance people on the job without increasing the total number of personnel in DOD. And, these savings do not include those that can be expected from improved maintenance efficiency. The types

of gains being considered are of the same magnitude as when automobile manufacturers changed their mode of operation to production lines.

Improved Aptitude Tests (Block 8). The results of the JTPT batteries administered in Blocks 4 and 7 would provide a data bank for the development of an improved aptitude test battery. Since the new aptitude test battery would be standardized against measurements of ability to perform job tasks, the objective of TOT, the prediction of such a battery for the initial training and job success should be improved over current batteries. The use of aptitude tests based on ability to perform job tasks, as well as, the use of JTPT for determining training success would result in a great improvement of the DOD posture concerning the previously mentioned EEO rulings of the U.S. Supreme Court. The Office Products Division of IBM has developed and is using such an aptitude test battery, which has been validated against training success and field performance, as measured by job task performance.

Second Term Training (Block 12). It is envisioned that there would be several such courses in each service, each course being aimed at an extensive cluster of hardware. Each such hardware cluster would probably reflect a limited number of vintages of hardware design. Selection for one of these courses would consider both the needs of the service and the desires of the individual. An individual could be selected for training for a cluster of hardware which does not match his initial assignment. The personnel selected for the broad-based training, indicated in Block 12, would have several advantages over those now receiving lengthy entry training. An important advantage is a well developed real-world frame of reference concerning maintenance. This will make broad-based training much more effective. Since only selected experienced people with a long term commitment would attend such a course, their motivation to learn should be high.

Such training programs to be effective would require extremely careful planning and execution. Each program should be based on a careful study and analysis of the expected job utilization of its graduates. As indicated in the task guidance display for Blocks 12 and 13, graduates would use FPJPA for most tasks. They would also be expected to use and have available several additional categories of maintenance guidance and information which include the unique SIMS or FOMM categories; i.e., maintenance dependency charts (MDC), blocked schematics, and keyed information. As a result, a large portion of each broad-

based training program should include a large amount of "hands on" activity solving many difficult maintenance problems using these documents.

Utilization of Graduates of Second Term Training (Block 13). The graduate of one of these broadbased courses would truly be a generalist and could provide several valuable functions. They could provide backup for first term personnel assigned to hardware with FPJPA. They would also be expected to perform maintenance on hardware for which no FPJPA are available including the performance of maintenance on transient aircraft.

A probably more effective and less costly scheme for utilizing some of these graduates and for providing at least part of the required backup capabilities would be a centralized maintenance information center, which could be called by telephone whenever a difficult problem is encountered. A highly trained expert, for each hardware system being maintained, would be assigned to such a center. Such a center could reduce the number of highly trained backup personnel required in the field for all hardware. In cases where only a few items of a specific hardware have been procured by DOD, it could possibly be used as a substitute for costly maintenance instructions and special training. this concept was recommended in one of the early AFHRL job performance aid technical reports (Folley & Shettel, 1962). A modification of this concept is being used successfully by the Office Products Division of IBM.

Appropriate Utilization of SIMS and FOMM (Blocks 12 and 13). An appropriate utilization of SIMS type data including FOMM is also indicated on the flow chart (Figure 2) in conjunction with Blocks 12 and 13. As mentioned previously hard data indicate that such aids improve the TS performance of highly trained and experienced personnel. Three versions of SIMS data are indicated on Table 2; i.e., traditional SIMS, Air Force SIMS and FOMM. The hard data concerning SIMS was gathered from the use of Air Force type of SIMS. Currently there are no data which indicate that FOMM is more effective than Air Force SIMS.

There are only three categories of SIMS type aids which impact TS performance more than TMM and these are included in the list of nine guidance and information categories for experienced and highly trained personnel (see Figure 2, Blocks 12 and 13). They are the MDC, blocked schematics, and keyed information. Although the specifications cited in Table 2 for traditional SIMS and for FOMM provide for some step-by-step in-

structions for non-TS tasks, these instructions are of the traditional variety found in TMM. (FPJPA for non-TS tasks are, therefore, much more effective.)

The MDC is the heart of the SIMS TS concept; however, the human factors characteristics of the MDC vary greatly among the various versions of SIMS. An analysis of the characteristics displayed in Table 5 indicates that the Air Force type of SIMS is superior from a human factors point of view, containing some of the features of the FPJPA technology. AF SIMS contain step-by-step checkout procedures in standard language and each component mentioned is keyed to a locator pictorial. In addition, the symbology used for indicating dependencies in Air Force SIMS is the least complex for these aids.

When the checkout procedures of the MDC identify an out-of-tolerance condition, the chart provides a set of dependent functional units, the fault to be identified being within the set. That is, "it gets the maintainer in the right ball park fast." (To be effective each set of dependencies must be complete.) From this point on, he must plot his own course of action making use of the hardware descriptions found in the block schematics and keyed information. It is during this "free wheeling" activity that the maintainer can make costly errors resulting in inefficient TS.

IV. CURRENT KEY RESEARCH AND IMPLEMENTATION ACTIVITIES

Army Implementation Activities

It will be recalled that the Army supported over half of the early R&D concerning TOT, including the important FORECAST effort which, also, produced the effective FORECAST TS aids discussed previously. And the Army is now in the forefront concerning implementation. The Army's integrated Technical Documentation and Training (ITDT) Program is by far the boldest and most far reaching implementation action ever taken to exploit the benefits of IMG&I, TOT and the IMG&I/TOT trade off. This program already contains many of the aspects, displayed in Figure 2, for shortening of initial training of first enlistment personnel, as well as the decentralization of such training by providing TOT packages and by assigning the responsibility for initial training to operational units. This program is being institutionalized by the Mil-M-630XX series of specifications. *As will be discussed later, these specifications do require major modifications if the expected and necessary results of IMG&I and*

TOT technologies are to be achieved; however, they do provide the overall framework for more effective and efficient utilization of first enlistment personnel provided the necessary specification modifications are made.

Navy Research Program

The Navy is the only service which is and has consistently supported R&D concerning FPJPA/TOT tradeoff. Starting in 1972, the Human Factors Engineering Division of the Naval Air Development Center (NADC) supported an effort which has resulted in a controlled comparative study (Theisen et al., 1978) which produced hard data attesting to the feasibility and effectiveness of the FPJPA/TOT trade off. In fact, it is the only such controlled trade off study which has been completed to date. Currently, the NADC at San Diego, California, has a new 3-year advanced development project which is aimed not only at refining the IMG&I/TOT trade off, but more importantly at solving the personnel and training implementation problems. This project No. Z0828PN entitled "Job Performance Aid Test and Evaluation," should result in the necessary guidelines for optimum FPJPA/TOT trade offs. As of February 1978, proposals for this work were being evaluated.

Navy Work Packages

The Navy Air Systems Command (NAVAIR) has developed the Mil-M-819XX(AS) series of specifications which include provisions for work packages that are a decided improvement, when compared with TMM. Each such work package is designed to support the performance of one non-TS or TS maintenance task. A common aspect of each work package is that it contains a consolidated presentation of available information and guidance pertaining to a task; materials, which are normally dispersed throughout TMM. Since each work package is task oriented, the FPJPA technology and the work package concept are compatible. Many work packages reflect, at least, the format aspects of the FPJPA technology. However, the specifications contain no firm requirements for applying the FPJPA technology including no firm requirement for task identification and analysis (TIA). NAVAIR requires the development of work packages for all new systems. The work package concept certainly is an improvement over TMM and provides the framework for a full implementation of the results of the recently completed NADC FPJPA/TOT trade off R&D (Theisen et al., 1978).

Table 5. Indicating Key Human Factors Characteristics of Three Versions of SIMS Type MDC

Parts of Chart	Air Force SIMS MIL-M-38799	Traditional SIMS MIL-M-24100A (Ships)	FORMM MIL-M-24100B
X-Axis	<ol style="list-style-type: none"> 1. Step-by-step checkout procedure 2. Standard language requirement 3. Keyed pictorial components mentioned 	<ol style="list-style-type: none"> 1. Step-by-step checkout procedure 2. No Standard language requirement 3. No pictorial locators 	<ol style="list-style-type: none"> 1. Step-by-step checkout procedure 2. No standard language requirement 3. No pictorial locators
Y-Axis	<ol style="list-style-type: none"> 1. Functional units listed 2. Column for each functional unit 3. Keyed pictorial locator for each functional unit 	<ol style="list-style-type: none"> 1. Functional units listed 2. Column for each functional unit 3. No pictorial locators 	<ol style="list-style-type: none"> 1. Functional units listed 2. Column for each functional unit 3. Alternate columns in color 4. No pictorial locators
Body or Cells (Displays dependency sets made up of abstract symbols)		<ol style="list-style-type: none"> 1. Lowest number of abstract symbols to be learned by user 2. Least complex dependency sets 	<ol style="list-style-type: none"> 1. More symbols to be learned than for AF SIMS 2. Dependency sets more complex than for AF SIMS

Current Air Force R&D and Implementation Activities

The Air Force supported the initial development work of the TI&A technology which has been basic to the more recent developments of job effective IMG&I and TOT by the Army and Navy (Miller & Folley, 1951; Miller, 1953). Also, the Air Force conducted the first TOT study which started in 1953 (Foley, 1964) and supported most of the exploratory development and early advanced development of the FPJPA technology (Joyce et al., 1973a, 1973b, 1973c). In addition, the Air Force conducted a preliminary, uncontrolled demonstration of FPJPA/TOT trade off (Mullen & Joyce, 1974). However, the Air Force did not fund planned controlled comparative research concerning such trade offs.

As far as the Air Force implementation of the FPJPA technology is concerned, the technology, as developed is based on TI&A and is applicable to both non-TS and TS tasks for both the organizational and intermediate levels of maintenance. However, *implementations, to date, have concerned only non-TS tasks for the organizational maintenance of aircraft.* Job Guide Manuals (JGM) for organizational maintenance in FPJPA format have been developed for the C-141, B-52, KC-135, F-106 (partial), F-5E, and the A-10 aircraft. They are being developed for the F-16 and are planned for the Advanced Medium STOL Transport (AMST), as well as, for various other sub-systems for the Aeronautical Systems Division (ASD) and Electronic Systems Division (ESD). Such JGM were also planned for the B-1. Of these JGM developments, the C-141 JGM are the only manuals which reflect the TI&A aspects of the FPJPA technology.

However, (as mentioned earlier) the AFHRL, at the request of Air Force Logistics Command (AFLC), is now developing a specification under contract for TI&A. In addition, a specification for LTTA is being developed under the same contract. Some consideration is also being given to expand this same mix of IMG&I (JGM for non-TS tasks and LTTA for TS tasks) to the organizational maintenance of other hardware, as well as to intermediate maintenance. Such improved applications should greatly improve the efficiency of maintenance, but will not set the stage for the maximum utilization of first enlistment personnel by effective FPJPA/TOT trade off as indicated in Figure 2.

Industrial Implementation Efforts

Five industrial organizations have been identified for their advanced approaches to TI&A,

IMG&I, training and/or personnel utilization. They are the two steel corporations, Armco Corp, and U.S. Steel; the Cleveland Engine Plant of Ford Motor Company; the Office Products Division of the IBM; and the Bell System. These advanced industrial approaches are very similar to those presented and recommended for DOD implementation. All of these applications can be traced to human factors R&D supported by the military services. In general, the military services have been ahead of industry in human factors R&D for maintenance, but behind some industries in applications.

Of these industrial organizations the Office Products Division of IBM has the most impressive integrated system of personnel utilization. This integrated system has many of the characteristics of the proposed program, outlined in Figure 2, which include effective IMG&I/TOT trade offs; all training success and job advancement are based primarily on ability to perform job tasks as measured by JPTTs; personnel selection procedures have been validated against such tests; the responsibility for the maintenance manual development, engineering changes, aptitude test development, formal training development and execution, field training packages development and performance assessment center operation are under one directorate; and the actual selection, hiring, and initial training of maintenance personnel have been decentralized and are the responsibility of the line managers in the field. An important aspect of this IBM program for DOD executives and managers is that the program is operating and has been operating successfully for several years.

The Bell System is probably the greatest user of TI&A for solving operator and maintenance personnel and training problems. A reflection of the Bell System's strong interest in TI&A was its sponsorship of a "Conference on Uses of Task Analysis in the Bell System," in October 1972. However, Bell does not have as formal and precise trade offs of TOT and IMG&I as does IBM. The applications made by Bell Systems are for solving specific problems. Important ingredients for Bell System's ongoing applications of the FPJPA technology have been the development of an internal guide for the preparation FPJPA, as well as an accompanying training program for FPJPA developers. These efforts were accomplished under the auspices of the Bell Laboratories. With some modifications, this training is now one of the Bell Laboratory's regular and popular courses given at Piscataway, New Jersey, for Bell System's managers, the idea being to greatly reduce or eli-

minate much costly training by using good job instructions. Another version of this training program is given by New England Bell at Marlborough, Massachusetts.

The Armco and U.S. Steel IMG&I/TOT applications are very similar, both being originally applied to the maintenance of the electronic controls on their rolling mills. Both organizations turned to the IMG&I/TOT technologies after traditional training approaches resulted in expensive maintenance failures. Both organizations have now applied IMG&I to other maintenance problems. A description and discussion concerning the Armco experience is reported in an issue of *Iron Age* (Snodgress, 1976). More recently the Cleveland Engine Plant of the Ford Motor Company is having an IMG&I/TOT program developed for the maintenance of its programmed control production equipment.

V. PROBLEMS AND POLICIES WHICH IMPEDE IMPLEMENTATION

1. DOD lacks a policy requiring that only those technologies and concepts whose effectiveness are supported by comparative hard data should be considered for implementation. Sales talk and "eye appeal" are unacceptable bases for expending large sums of operational money for untested concepts or proposed technologies even if they are innovative. Only those concepts and technologies should be implemented for operational purposes whose effectiveness for maintenance and/or training is supported by comparative hard data obtained from well designed and controlled tryouts.

2. Getting well developed and adequately tested technologies, such as FPJPA and TOT institutionalized, is a perennial problem, especially when a technology requires fundamental changes in long existing programs, procedures, and attitudes of entrenched establishments. The Advanced Systems Division of AFHRL has been involved in the implementation of several well developed and documented technologies, such as FPJPA and instructional systems design (ISD) including programmed instruction and job (task) oriented training. These experiences have indicated that it is extremely difficult to maintain the integrity of a technology during its so called implementation. Operational organizations invariably attempt to implement a much "watered down" version of the technology and consequently obtain much "watered down" results. In some cases, only cosmetic changes to existing programs are reported as

implementations. Currently, it requires years of persistent effort on the part of the research community to get a technology properly institutionalized. All of the current operational implementations of the FPJPA, the FORECAST, and TOT technologies have suffered or are suffering from this "watering down" phenomenon. Examples include most Air Force developments of so-called JGMs for organizational maintenance for existing and new weapons systems (Mil-M-38800), Army developments of Integrated Technical Documentation and Training (ITDT) systems, and the Air Force TOT implementations including BRIGHT SPARK and ABLE CHIEF.

3. A mechanism must be developed for the timely institutionalization of each promising new technology, which will ensure its integrity. A mechanism for the orderly implementation of technologies similar to that used for new weapons systems is recommended. Such a mechanism must make efficient and effective use of the "know how" of the developers of the technology and make them responsible and accountable for its implementation. A new technology should not be turned over to a using command for its operation until it is in place, "debugged" and operational—just as a new weapons system is not turned over to an operational command until it has been "debugged" and proven to be ready for operational use.

4. Although the proper implementation of quality TOT and FPJPA technologies will result in dramatic savings in overall maintenance labor costs in dramatic reductions in spare parts consumption, their implementation will require relatively large investments in quality maintenance guidance and information and in quality TOT programs, as well as, changes in personnel and training systems. Such necessary changes will require an integrated and concerned effort on the parts of the maintenance, the technical data, the training, the personnel, and the R&D establishments. All actions of the affected establishments must be aimed at maximizing the utilization and efficiency of first term maintenance personnel.

5. To develop the quality of maintenance documents necessary to effect the overall maintenance improvements and reductions in maintenance labor costs, will require at least from 50 to 100 percent more money than the Maintenance Manual Establishments have been accustomed to spend for current maintenance guidance and information. The budget managers must realize that this is a one-time, front-end investment that must be made in order to obtain the desired system life time cost reductions. Whatever is lacking in the

maintenance guidance documents must be supplied during every year of system life by more training, more support and test equipment, more spare parts, larger inventories of major hardware components, and more depot maintenance.

6. *Although shorter, quality, TOT is not cheap training. Most of the training time (to be effective) must be spent in "hands on" practice of key job tasks. This type of training cannot be obtained in "training" facilities: consisting of classrooms, podiums, tablet arm chairs, blackboards, and projectors.* Effective TOT requires substantially higher instructor to student ratios than DOD manpower establishments are accustomed to tolerate. Such training also requires larger investments in hardware, hardware simulators, pictorial simulators, and part task trainers. So the per week or per day cost of TOT will be greater than conventional maintenance training, especially for electronic hardware. For example, A TOT program (which is only 25 percent of the current length of a conventional program) may cost four or five times more per week, making the total operating cost of producing a graduate the same or slightly higher than the current program. *Budget managers must realize that this is another price that must be paid.*

7. *To insure maximum cost effectiveness from the implementation of a FPJPA/TOT model similar to that shown in Figure 2, the training and job success of first term DOD maintainers must be based on demonstrated ability to perform job tasks. This requires the utilization of JTPT batteries as the criteria for training and job success of first term maintainers, as well as the abandonment of traditional paper-and-pencil theory and job knowledge tests for such personnel.* TOT does not prepare people to pass such paper-and-pencil tests. With regard to an effective JTPT battery, FPJPA will provide for much of the interface between maintainer and his hardware. Therefore, it can be assumed for sampling purposes that, if the maintainer can demonstrate his ability to perform a limited number of key and difficult tasks of his job (using FPJPA) plus his ability to use test equipment and hand tools, he can perform most of his job tasks. Because of this characteristic of the FPJPA/TOT trade off, the amount and cost of training hardware necessary to provide hands on practice of representative tasks for quality TOT (based on a quality FPJPA/TOT trade off) should be much less than that required for quality TOT supporting TMM.

8. It is proposed that the responsibility for conducting field TOT training programs be given the maintenance establishment. This would fix the

responsibility for training with the people who must live with the results. In addition to conducting the broadbased training for second term personnel, the training establishments should have the job of preparing and updating the TOT training packages, as well as of training the appropriate members of the maintenance establishment to conduct such TOT.

9. To insure the integrity and effectiveness of both the initial TOT and their associated JTPT batteries, job assessment centers are proposed. Each center would be a joint effort with the appropriate training establishment. *Selected graduates* of entry training programs should be given a battery of JTPT, which would ascertain the effectiveness of entry training programs. The same job assessment center could be used to ascertain the job effectiveness of randomly selected experienced maintenance personnel. *The bank of data obtained from such centers should be used to standardize entry aptitude tests.*

10. To implement the model and to effect the savings, described in Figure 2, will require the reclustering of hardware for maintenance assignment codes for first term maintainers to which the model is applied. This will probably require a new maintenance assignment code for each cluster of hardware to which the FPJPA/TOT trade offs are applied. The number of hardware in a cluster should be manageable. For early applications, the maintenance of each cluster should require a large concentration of maintainers and if possible, all hardware in the cluster should reflect a limited number of design vintages. Such reclustering is required because all FPJPA/TOT trade offs must be based on the same trade off ground rules, and the FPJPA for each hardware in the cluster must be of the same high quality. (The reader is reminded that Table 3 indicates three possible combinations of IMG&I, the implementation of which could result in cost effective tradeoffs with TOT. However, the use of FPJPA technology for TS and non-TS tasks is emphasized in this paper, because this option is the most effective for maximizing the utilization of first-term maintainers).

11. It is again emphasized that the realization of such gains, as indicated in Figure 2, require that the integrity of advanced technologies be maintained during their implementation. It is absolutely necessary that their integrity be reflected in the official specification, guidance documents, policies, and well written work statements in contracts. In this regard, the current DOD official specifications and guidance concerning IMG&I technologies have serious deficiencies. For

example, Mil-M-38800 concerning JGM reflects format aspects of the FPJPA technology, but not the important TI&A aspects. In addition, the FPJPA technology covers both non-TS and TS tasks for both organizational and intermediate levels of maintenance, but Mil-M-38800 is limited to only non-TS tasks for the organizational level maintenance of aircraft. However, AFLC has requested AFHRL assistance for correcting at least part of these shortcomings. Mil-M-38799 concerning Air Force type SIMS does not require TI&A. Although the Mil-M-630XX series, developed by Army DARCOM, provides for TI&A but not for important inprocess reviews. In addition, the effectiveness of the types of IMG&I specified by the Mil-M-630XX series documents are not supported by comparative hard data.

12. However, the existence of specification and other guidance documents (which accurately reflect IMG&I and TOT technologies) does not insure that individuals within the affected establishments will or can implement such technologies properly. Technologies (such as, FPJPA, FORECAST, TOT, and JTPT) require many people in the training, personnel, maintenance, maintenance manual and industrial establishments to modify or change many of their long standing attitudes and behaviors. In addition to overcoming their natural resistance to change, many must learn important tasks and skills which they do not now possess. These people problems call for well planned and executed actions including the following:

a. Appropriate training programs concerning improved technologies for affected managers, supervisors and journeymen. The programs should result in certification for both DOD and contractor personnel, based on supervised practice and demonstrated ability to perform the required skills. These training programs should stress the required integration of technologies. (The certification of contractor personnel may require some modification of current DOD policies).

b. The establishment of in-house capability to perform inprocess reviews of contractor developed subproducts of TI&A and the application of these subproducts to IMG&I and TOT developments.

c. The establishment of an appropriate mechanism for insuring the effective integration of IMG&I, TOT, and JTPT technologies.

13. The tremendous savings to be realized from the implementation of IMG&I, TOT, and JTPT will be reflected in the maintenance establishments. However, the substantial investments required to effect these savings must be made by the technical manual, training and personnel establishments. Currently, the effectiveness of managers in each of these investment establishments is not measured by the savings they effect in the maintenance establishments. Current funding practice uses past expenditures for each individual establishment as budgeting criteria for its future expenditures. A mechanism must be established which will provide sufficient additional funds for these necessary investments in quality IMG&I, TOT, and JTPT.

14. An important consideration for the development of DOD policy encouraging effective applications of IMG&I, TOT, and JTPT technologies is their potential for rapid build up of both new and reserve personnel in times of national emergencies. In place, quality integrations of FPJPA, TOT, and JTPT technologies for key hardware would not only greatly reduce build up time, but would also, reduce the number of spare parts used at a time when spare parts would probably be in short supply.

15. Since so many now independently operating establishments must work in concert to effect necessary changes, an agency must be established having the necessary power and "know how" to effect necessary changes. The Office Products Division of IBM accomplished this important function by making the same general manager responsible for the development and conduct of formal training, the development of field training packages, the development of on the job task guidance documents, the development and validation of aptitude tests, and the conduct of their job assessment center. This structure provided the necessary power to effect such an integration, but not the necessary "know how." The "know how" has been provided by an expert human engineer, and management followed his directions. The application of power unaccompanied by in-depth "know how" is an extremely dangerous combination when dealing with complexed technologies.

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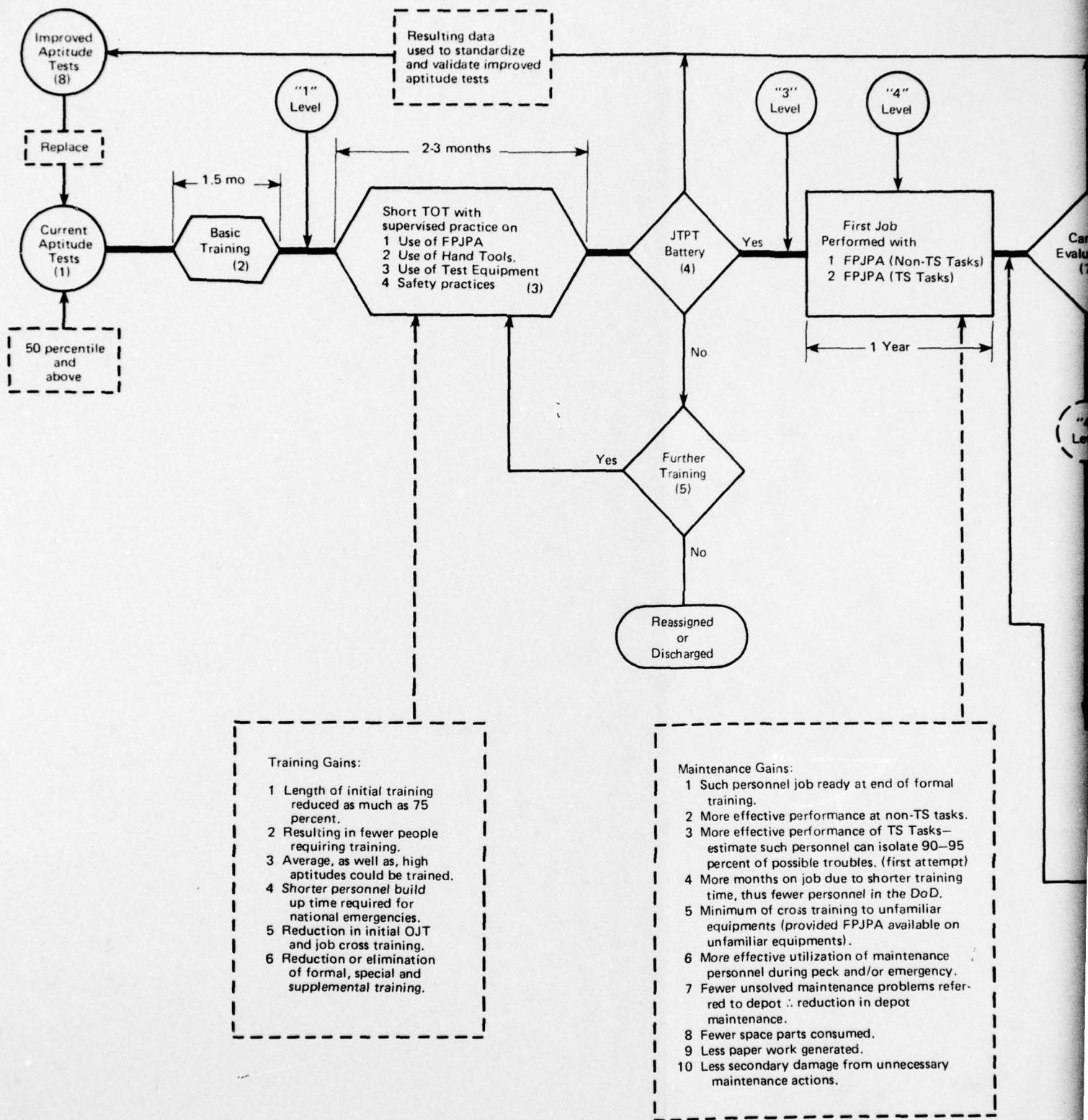


Figure 2. Annotated flow diagram portra

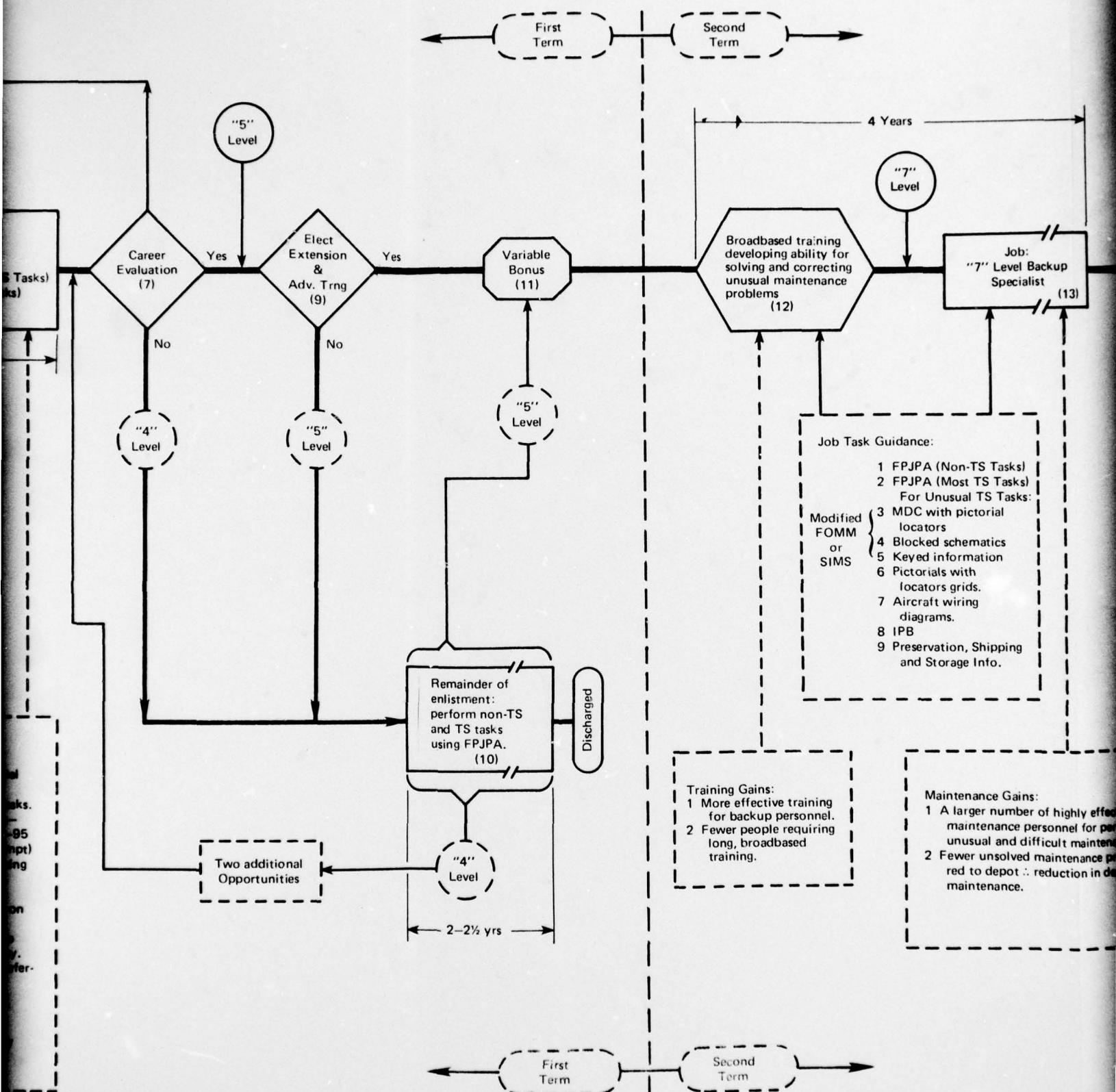
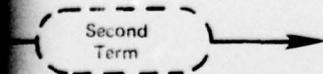
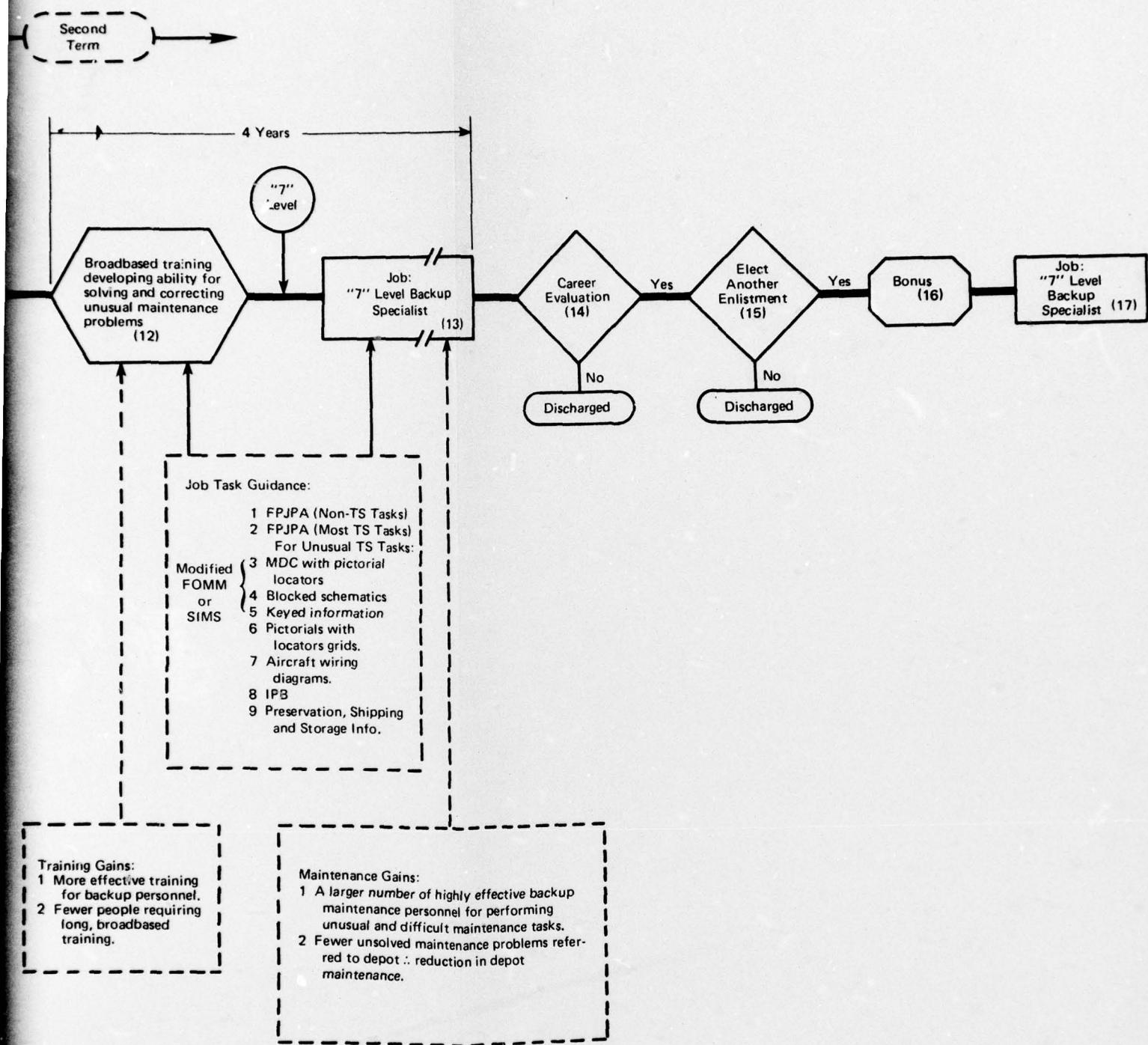


Diagram portraying a model for maximizing benefits of FPJPA, SIMS and TOT technologies.



analogies.